WESTERN GREAT BASIN PROVINCE (018)

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INTRODUCTION

Province 18 is basically the western part of the Great Basin physiographic section and includes parts of northeastern California, western Nevada (west of longitude 117^{o} W.), and southeastern and south-central Oregon, along with eastern California east of the San Andreas Fault and the Sierra Nevada. The province is 840 mi long and 60 to 250 mi wide. The surface area is about 130,000 sq mi.

The basement rocks of the western Great Basin consist of Paleozoic to Mesozoic carbonate and clastic rocks that underwent three major compressive orogenic events in the late Paleozoic to early Mesozoic period. Heating related to these orogenic events and widespread igneous intrusion and metamorphism in the middle to late Mesozoic largely destroyed the hydrocarbon- generation potential of the basement rocks. Cretaceous through Cenozoic time has been characterized by lacustrine and fluvial deposition overprinted by extensional faulting, volcanism, high heat flow and hydrothermal alteration in the Neogene. The Neogene extensional tectonics formed the Basin and Range physiographic province, which is characterized by north-south- trending ranges truncated at the range front by normal faults that form adjacent basins. The ranges and the floors of the basins consist of Paleozoic and Mesozoic rocks that are generally overmature and have no source rock potential in Province 18. Cenozoic lacustrine and fluvial rocks infilling the basins locally have hydrocarbon-generation potential.

The hypothetical plays defined for this province are based on the presence of source rocks having demonstrated hydrocarbon potential. Triassic carbonate source rocks have oil potential in portions of the Stillwater, Clan Alpine and Augusta Mountains of west central Nevada. Late Triassic rocks in east central Oregon have traces of oil in them (Brown and Ruth Laboratories, 1983). Jurassic (?) to Cretaceous lacustrine rocks have source rock potential in the Black Rock Desert and Jackson Range of Nevada. Potential Cenozoic source rocks are found throughout the province, but most have reached only marginal thermal maturity except in areas of high heat flow (Kinney, 1976). These Cenozoic, mostly Neogene, source rocks are present in almost all Basin-and-Range-type basins (Hastings, 1979; Garside & Papke, 1980; Bortz, 1983; Alldredge and Meigs, 1984; Barker and Barker, 1985; Montgomery, 1988a, b; Hess, 1990). Some Cenozoic source rocks contain algal organic matter in lacustrine marls and humic coals or coaly rocks. Oil and gas generation occurred during high heat flow in the Neogene. Numerous gas shows are found in most Cenozoic basins of the Western Great Basin Province (Brady, 1984). The gas shows are thought to be largely biogenic in the shallow subsurface, but deeper gas shows , especially in southeastern Oregon, northeastern California, and northwestern Nevada, are likely thermogenic in origin. A few oil shows and seeps are documented in the north and central parts of Province 18

(McDaniels, 1985; Garside and others, 1988; Schalla and others, 1994). The oil shows in Cenozoic rocks are typically, and perhaps genetically, related to contact or hydrothermal metamorphism. All of the major plays have been tested by drilling, but no commercial production has been established in Province 18. The major traps and reservoir rocks in this province are thought to be formed by (1) folding and fault truncation related to Mesozoic thrusts of Paleozoic and Mesozoic carbonate and clastic rocks; (2) fault truncation at the basin margins of reservoirs formed by fracture- enhanced permeability in Paleozoic and Mesozoic carbonate and clastic rocks or interbedded Cenozoic lacustrine, fluvial and alluvial rocks; (3) sand bodies or pockets having high primary or secondary porosity encased in low-permeability volcanogenic or lacustrine sediments; and (4) fractured tuffs and volcanic flows.

Four hypothetical conventional plays were assessed. They are Hornbrook Basin–Modoc Plateau Play (1801); Eastern Oregon Neogene Basins Play (1802); Permian-Triassic Source Rocks, Northwestern Nevada and East Central and Eastern Oregon Play (1803); Cretaceous Source Rocks, Northwestern Nevada Play (1804); and Neogene Source Rocks, Northwestern Nevada and Eastern California Play (1805).

HYPOTHETICAL PLAY DEFINITION TECHNIQUE

To define the hypothetical play boundaries in the Neogene basins, we used a series of overlays that (1) outline areas of Tertiary-Quaternary fill in basins (usually grabens) from the Nevada 1:500,000 geologic map; (2) use gravity data (Jachens and Moring, 1990; Blakely and Jachens (1991); or other gravity data) to reduce the play area to where the Tertiary fill is deep (1 to 2 km or so; based on the conclusions of Barker and Peterson, 1991) ; and (3) extend the play into more shallowly buried parts of the basin adjacent to the deep burial area or where hydrocarbon shows or seeps are known (Brady, 1984; Garside and others, 1988; Schalla and others, 1994).

ACKNOWLEDGMENTS

Scientists affiliated with the American Association of Petroleum Geologists and from various State geological surveys contributed significantly to play concepts and definitions. Their contributions are gratefully acknowledged.

CONVENTIONAL PLAYS

1801. HORNBROOK BASIN–MODOC PLATEAU PLAY (HYPOTHETICAL)

This hypothetical play is based on known terrestrial Cretaceous or Tertiary source rocks and the speculative presence of Cretaceous marine source rocks that are buried beneath Cenozoic sedimentary rocks and (or) Cascade volcanics in the Hornbrook Basin–Modoc Plateau to Honey Lake area.

Reservoirs: Reservoir formations include Cretaceous and Tertiary sandstones and fractured Cascade volcanics or pyroclastics. Seals consist of overlying or draping mudstones; well-cemented sandstones or diagenetically altered or Neogene tuffs (Alldredge and Meigs, 1984; Fuis and others, 1987; Montgomery, 1988).

Traps: Traps are large antiforms expressed at the surface in the volcanic flows, truncation of interbedded reservoir and seal rocks by Basin-and-Range-type block faults and mudrock-draped offshore bars and shoreline facies.

Source rocks: Source rocks are Type III or II in the Cretaceous rocks or Type I and III in the Tertiary rocks. Thermal maturity is marginal, mostly less than 0.7 percent mean random vitrinite reflectance (R_O), Law and others (1985). The confirmation of marine source rocks in the play would enhance the commercial viability of this play.

Exploration status and resource potential: Some biogenic gas shows have been noted, but there is no production. Drilling is sparse and many wells do not penetrate through the thick volcanic section. If this play was demonstrated to have Marine source rocks and in the Large Antiforms were viable traps and reservoirs this play could have a large resource potential.

1802. EASTERN OREGON NEOGENE BASINS PLAY (HYPOTHETICAL)

This hypothetical play in the Lakeview, Harney, Malheur and Snake River basins, and other east- central or eastern Oregon Neogene basins is based on present-day burial of known Neogene type III and possibly Type I (lacustrine) source rocks (Tennyson and Parrish, 1987; Wermeil, 1987; Olmstead, 1988).

Reservoirs: Reservoir formations include fractured Neogene welded tuff and basalt, Miocene fluvial sandstone intercalated with basalt, upper Miocene and younger fluvial sandstones.

Traps: Stratigraphic traps formed where porous reservoirs are encased in carbonate- and zeolite-cemented sandstones, and where local lenticular sandstones grade into mudrock. Diatomite-rich sequences may be poor seals and enable gas to escape to the atmosphere as it forms. Structural traps can be formed by fault truncation of reservoir rocks, local anticlines with closure, open fracture lattices in basalt and ignimbrite, fluvial sandstone lenses between basalt flows, and local porous, diatomite-rich

lenses. Seals are formed by reservoir pods of fractured volcanic lithologies and porous fluvial sandstone in densely cemented sedimentary and welded volcanic strata.

Source rocks: Source rocks are Neogene (6 to 14 Ma) coals and carbonaceous lacustrine rocks. Thermal maturity ranges from <0.4 percent to at least 1.6 percent R_O. Lacustrine shales containing terrestrial organic matter are known to reach 1.6 wt. percent total organic carbon (TOC) and have a very low hydrogen index (<25). Measured well temperatures commonly exceed 100^o C and the organic-rich rocks thermally mature in these areas (Bowen and others, 1977).

Exploration status and resource potential: There are common shows of gas at shallow depth that are speculated to be biogenic (?) in origin but no production has been established. Gas quantities generally increase towards igneous intrusions in the area suggesting that some thermogenic gas is present in warmer areas. Wells drilled into the large antiforms in the volcanic rocks of the Lakeview Basin had only gas shows from Cenozoic lacustrine rocks. Wells can be difficult to place as shown by two wells in this play that penetrate 8,000 and 10,000 ft of volcanic or volcanogenic sedimentary rocks having very low TOC content (mostly <0.5 wt. percent). The small reservoirs and traps found so far in this play suggest small resource potential.

1803. PERMIAN-TRIASSIC SOURCE ROCKS, NORTHWESTERN NEVADA, AND EAST-CENTRAL AND EASTERN OREGON PLAY (HYPOTHETICAL)

This hypothetical play is based on present-day deep burial and effective sealing of Permian-Triassic source rocks in Basin and Range type basins and horsts in Nevada and Oregon. The play is based on speculation that in some fault blocks the Permian-Triassic rocks may have potential for petroleum generation that was preserved until now when they are deeply buried and heated by burial, and by hydrothermal, and contact metamorphism (Bortz, 1983; Oldow and Tipnis, 1984).

Reservoirs: Reservoir formations include Permian to Triassic sandstones and limestones and overlying basin-margin alluvial fans and fractured volcanic rocks.

Traps: Traps are formed by drag folds and (or) truncation related to imbricate thrust sheets in the Fencemaker and Willow Creek thrust systems and by fault truncation within the Neogene basins or at their margins. Traps may also be formed by fault-bounded sub blocks within the horsts that form the ranges in the area (Catchings, 1992). Seals are mudrocks and (or) faults. It is also possible that fractured source rocks may form reservoirs.

Source rocks: Source rocks are marine Permian to Triassic shales containing oil-prone organic matter in west- central Nevada and terrestrial organic matter in east-central Oregon (Brown and Ruth Laboratories, 1983). Preservation of source rock potential is spotty. Conodont alteration-index mapping by Harris and others (1980), vitrinite-reflectance measurements (McDaniels, 1982) and Rock-Eval analyses (Barker and

others, 1994) show most of the Triassic of the Western Great Basin Province is overmature. Organic geochemistry suggests the Triassic source rocks in west- central Nevada have a high TOC and hydrogen content. The ranges, rather than the basins, where there may have been a lower degree of contact, geothermal, or low-grade regional metamorphism may represent areas of Neogene oil generation and preservation. Pores within fossils from the Augusta and Clan Alpine Mountains can contain live oil. The limited source rock volume suggests this play has only a small resource potential.

Exploration status and resource potential: No wells test the oil potential of the ranges in this play. Neogene generation is considered important because any earlier hydrocarbon generation from these rocks is presumed lost due to the ongoing disruption of traps by extensional tectonics or igneous intrusions and contact metamorphism.

Wells drilled into the basins next to the Augusta and Clan Alpine ranges encountered overmature rocks and gas shows, but there has been no production (Garside and others, 1988; Barker and others., 1994). A 1993 mineral exploration well in Buena Vista Valley, near Kyle Hot Springs, west-central Nevada, produced an oil show that is apparently generated from Cenozoic lacustrine rocks and reservoired in fractured Triassic sedimentary rocks (Schalla and others, 1994). Active geothermal systems are present near all of these wells and throughout the area and may be the cause of the apparently local maturation of the source rocks.

1804. CRETACEOUS SOURCE ROCKS, NORTHWESTERN NEVADA PLAY (HYPOTHETICAL)

The hypothetical play is based on Neogene to present deep burial of Cretaceous source rocks in northwestern Nevada Neogene basins (Widen, 1979). This play considers any Neogene basins containing deep valley fill to be conceptually prospective (on the basis of conclusions of Barker and Peterson, 1991).

Reservoirs: Reservoir formations include lacustrine beds laterally interbedded with marginal alluvial fans or sandstones interbedded with the Jurassic (?) to Cretaceous lacustrine beds and fractured Tertiary volcanic rocks.

Traps: Trapping mechanisms are fault truncation of reservoir rocks, mudstone-draped lenticular sandstones, and Neogene lacustrine beds laterally interbedded with marginal alluvial fans (overlying seal formed by continental evaporites, mudstones, altered volcanic tuffs or flows; lateral seal formed by fault truncation).

Source rocks: Cretaceous source rocks are apparently locally mature and have produced oil and gas shows but no discoveries. Thermal maturation may also have occurred by heating of source rocks by geothermal convection, shallow intrusions, and fluid flow up basin faults, especially near the graben boundaries. The source rocks in this play may be mature to overmature in areas of high heat flow and geothermal activity.

Exploration Status and Resource Potential: This play has been drilled and was found to be dry. The limited source rock volume and marginal quality suggest a small resource potential.

1805. NEOGENE SOURCE ROCKS,. NORTHWESTERN NEVADA AND EASTERN CALIFORNIA PLAY (HYPOTHETICAL)

This hypothetical play is based on deep Neogene to Recent burial of Miocene to Recent source rocks in northwestern Nevada and Eastern California Neogene basins. This play considers any Neogene to Recent basins containing deep valley fill to be conceptually prospective (on the basis of conclusions of Barker and Peterson, 1991).

Reservoirs: Reservoir formations include lacustrine beds laterally interbedded with marginal alluvial fans and fractured Tertiary volcanic rocks.

Traps: Trapping mechanisms are fault truncation of reservoir rocks, mudstone-draped lenticular sandstones, and Neogene lacustrine beds laterally interbedded with marginal alluvial fans (overlying seal formed by continental evaporites; lateral seal formed by fault truncation).

Source rocks: Tertiary source rocks are apparently locally mature and have produced oil and gas shows but no discoveries. Tertiary to Recent lacustrine rocks are immature when encountered at shallow depth in non-geothermal wells (Barker and Barker, 1985) . Thermal maturation may also have occurred by heating of source rocks by geothermal convection, shallow intrusions, and fluid flow up basin faults, especially near the graben boundaries (i.e. in areas of high heat flow; Kinney, 1976).

Exploration status and resource potential: The source rocks in this play may be mature to overmature in areas of high heat flow and geothermal activity. Only small reservoirs are expected in this play but source rock quality and quantity are high and the source rock has generated oil (Scholle and others, 1994) so the resource potential is moderate to high.

UNCONVENTIONAL PLAYS

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

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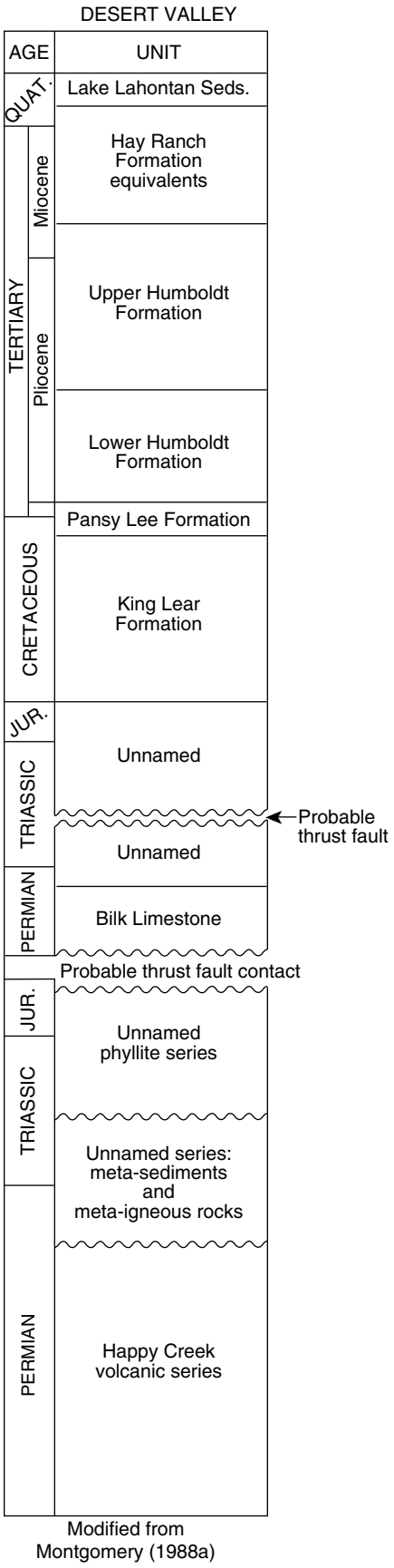
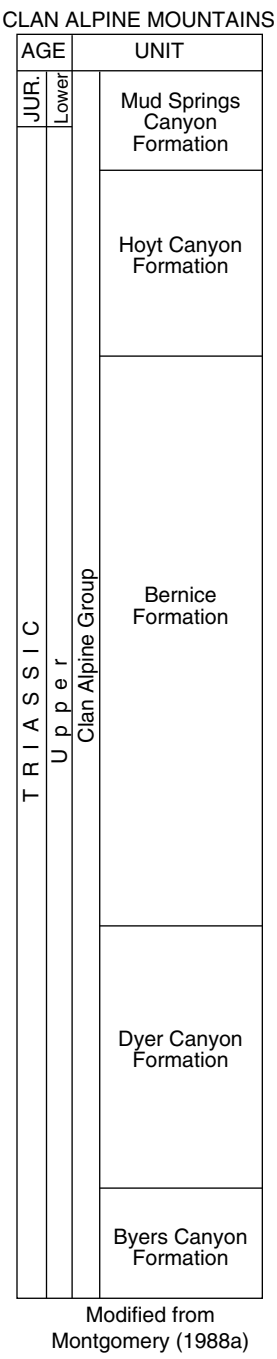
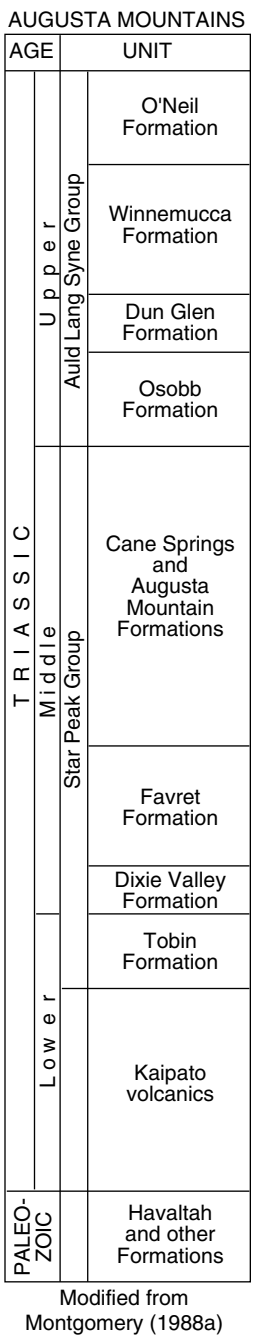
SOUTH-CENTRAL OREGON

AGE	SYSTEM	SERIES	FORMATION—GROUP—SEQUENCE
CENOZOIC	QUATERNARY	Pleistocene	Alluvium, Terrace deposits
	TERTIARY	Pliocene	Plio-Pleistocene volcanics, Rattlesnake, Mascall
		Miocene	Columbia River
		Oligocene	John Day
		Eocene	Clarno, Intrusive basalts throughout much of Cenozoic
		Paleocene	
MESOZOIC	CRETACEOUS	Upper	Gable Creek, Bernard, Hudspeth
		Lower	Nevadan granitoid intrusions
	JURASSIC		Lonesome, Shale in Snake, Trowbridge, River Gorge, Izee, Snowshoe, Hyde, Colpitts, Warm Springs, Weberg, Mowich, Nicely, Suplee, Graylock, Robertson, Donovan
	TRIASSIC		Murderers Creek, Rail Cabin, Laycock, Hurwall, Field Creek, Martin Bridge, Brisbois, Vester, Clover Cr., Gold Creek, Begg, Canyon Mtn., Clover Cr. ultrabasics
PALEOZOIC	PERMIAN		Elkhorn Ridge, Coyote Butte, Burnt Ridge Schist
	CARBONIFEROUS	Penn.	Spotted Ridge
		Miss.	Coffee Creek
	DEVONIAN		Beds at Binger Ranch

Modified from Bennison, 1973


DESERT VALLEY
AGE
UNIT
QUAT.
Lake Lahontan Seds.
TERTIARY
Miocene
Hay Ranch Formation equivalents
Pliocene
Upper Humboldt Formation
Lower Humboldt Formation
Pansy Lee Formation
CRETACEOUS
King Lear Formation
JUR.
TRIASSIC
Unnamed
Probable thrust fault
Unnamed
PERMIAN
Bilk Limestone
Probable thrust fault contact
JUR.
TRIASSIC
Unnamed phyllite series
Unnamed series: meta-sediments and meta-igneous rocks
PERMIAN
Happy Creek volcanic series
Modified from Montgomery (1988a)


CLAN ALPINE MOUNTAINS
AGE
UNIT
JUR.
Lower
TRIASSIC
Upper
Clan Alpine Group
Mud Springs Canyon Formation
Hoyt Canyon Formation
Bernice Formation
Dyer Canyon Formation
Byers Canyon Formation
Modified from Montgomery (1988a)


AUGUSTA MOUNTAINS
AGE
UNIT
TRIASSIC
Upper
Auld Lang Syne Group
O'Neil Formation
Winnemucca Formation
Dun Glen Formation
Osobb Formation
Middle
Star Peak Group
Cane Springs and Augusta Mountain Formations
Favret Formation
Dixie Valley Formation
Tobin Formation
Lower
Kaipato volcanics
PALEO-ZOIC
Havaltah and other Formations
Modified from Montgomery (1988a)